# Effects of Different Land Use on Soil Hydraulic Properties

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## Abstract

An understanding of hydraulic properties of surface soils is needed for sound soil management because it determines the partition of rainfall and snowmelt into runoff or soil water storage. The purpose of this study was to evaluate the effects of three land uses (native grassland, brome grassland and cultivated land) on soil physical properties. For each land use, water infiltration rates were measured with a tension infiltrometre at 3, 7, 15, and 22 cm water tensions. Total porosity and macro porosity were determined and hydraulic properties were estimated. The highest total porosity and macro porosity were observed in native grassland while cultivation had significantly reduced macro porosity. At 15 and 22 cm tensions native grassland had significantly lower infiltration rates than cultivated fields while brome grassland had intermediate infiltration rates. Surface soil hydraulic properties differ markedly among land uses, with grasslands having higher saturated hydraulic conductivity. The observations indicate that cultivated soils have lower macroporosity than grassland soils and, therefore, lower infiltration of rain and increased potential for runoff. In contrast, cultivated soils are able to absorb more rainfall and snowmelt under unsaturated conditions. Land use changes may alter the water balance of the area by changing the amount of surface runoff and therefore, any changes in existing land use must be done cautiously.

## Introduction

Knowledge on soil hydraulic properties such as infiltration rate, hydraulic conductivity and moisture retention is important in terms of Agriculture as well as environment quality because they control the rate of water flow and fate of nutrients, chemicals and pollutants in the soil system (Jaramillo et al., 2000). Understanding of surface soil hydraulic properties is also essential for sound land management as they determine the partition of rainfall and snowmelt into soil water storage or runoff.

Agricultural management practices and type of vegetation has a significant effect on soil properties that influence water movement. Tillage will alter structure and break the continuity of macropores network in the plough layer. This will reduce the infiltration rate of the soil (Maule and Reed, 1993). Tillage alters soil porosity and pore size distribution leading to changes in unsaturated hydraulic properties of the tilled layer (Edward et al., 1988). Use of heavy machinery in land preparation, inter-cultivation or harvesting may compact the soil. Compaction increases soil bulk density, destroy macropores, increase smaller pores and thereby decrease infiltration rate and hydraulic conductivity at saturation. Continuous cultivation decreases organic matter content in soil, reduces the aggregate stability (Peterson et al., 1988) and leave the surface bare and exposed to rainfall. Rainfall impacting on bare soil breaks down aggregates and leads to the formation of a surface crust. Presence of surface crust decreases infiltration and hydraulic conductivity.

Presence of grass cover or crop residues, on the other hand, reduce the effect of raindrop impact upon aggregate disruption while increased organic mater helps to strengthen soil aggregates (Wishmeier and Mannering, 1969). These factors prevent formation of surface seals and will help to maintain higher infiltration rates (Rawls et al., 1993) and higher hydraulic conductivity.

Land use in surrounding uplands can have an important effect on wetland (sloughs) water balance. Based on the studies on water level of wetlands in Southern prairie region of Canada, Van der Kamp et al. (2001) reported that conversion of cultivated lands into permanent undisturbed brome grass resulted in drying out of wetlands within the grassed area. These findings suggest that change in land use alter the hydrology of the prairies. Hence studies on the effect of different land uses on soil hydraulic properties of prairie soils are greatly needed. Van der Kamp et al. (2001) have studied the infiltration rate under saturated conditions. However, soils in cold semi-arid climate remains mostly under unsaturated condition. Hence, evaluation of soil hydraulic properties under controlled tension is of great importance.

**Objectives**

The objective of this study was to evaluate the effects of three land uses namely native grassland, brome grassland and cultivated land on infiltration rate and hydraulic conductivity under unsaturated conditions.

**Materials and Methods**

This study was carried out at St. Dennis National Wildlife Area located in Central Saskatchewan, Canada ($106^0$ 06'W, $52^0$ 02,N). The soil of the area is classified as Orthic Dark Brown Chernozems with the surface soil of clay loam in texture.

Study sites were chosen to represent three different land uses. An adjacent sites on the same soil type under two different pasture conditions, namely a permanent pasture (Native grass) and Brome grass (*Bromus inermis*) and a field under canola cultivation were used for the experiment. The native grassland had not been ever cultivated or disturbed since 1950,s. Canola field site had been under cultivation of wheat and canola in rotation. Between 1980 and 1983, a part of the cultivated land was converted to permanent undisturbed brome grassland with the intension of providing improved nesting cover for ducks.

In August 2001, six locations per land use were randomly selected and cumulative infiltration was measured using tension infiltrometre (Soil Measurement Systems, Tuscon, AZ) with 20 cm diameter disk. Infiltration measurements were taken at 3, 7, 15 and 22 cm $H_2O$ tensions. Measurements were continued at each tension until steady state is achieved. Before start the measurements, a soil core sample was also taken just outside the measurement area to determine the antecedent soil moisture content.

Soon after the infiltration measurements at 3 cm tension had been made an undisturbed soil core sample (5 cm dia. * 5 cm height) was taken from the surface soil layer. Weight of moisture and dry soil were obtained by oven drying and bulk density was calculated. Total porosity of soil was computed from bulk density and average particle density (Rawls et al., 1993). The difference between total porosity and volumetric moisture content held at 3 cm $H_2O$ tension was taken as the volume of macropores. Wooding's (1968) solution for approximate steady infiltration rate from a shallow circular disk was employed to estimate hydraulic properties (Jaramillo et al., 2000);

$$q_{o\infty} = \left(1 + \frac{4}{\alpha \pi rd}\right) K_s e^{\alpha h_0}$$

where $q_{o\infty}$ is the approximate steady state infiltration rate, $\alpha$ is a physical constant, and $K_s$ are the saturated hydraulic conductivity at defined pressure head ($h_0$) and disc radius (rd). Equation has two unknown parameters Ks and $\alpha$. These two unknown parameters were estimated by non-linear regression using steady state infiltration rates at different tensions.

## Results and Discussion

The effect of different land uses on bulk density, total porosity and macroporosity of surface 0-5 cm layer is shown in Table 1. The cultivated land had the highest bulk density while native grassland had the lowest bulk density. Bulk density values were significantly different (p=0.05) among land uses. Owing to the lowest bulk density, total porosity was found to be the highest for native grassland, followed by brome grassland and cultivated land in descending order. The total porosity values are consistent with the findings of Van der Kamp et al. (2001). Macropores among land uses were significantly different (p=0.05) with the highest value in native grassland followed by brome grassland and cultivated field in descending order. Cultivation has appeared to reduce macroporosity while grass cover tends to increase macroporosity.

**Table 1.** Bulk Density, Total Porosity, Macroporosity, Mean Saturated Hydraulic Conductivity (Ks) and Empirical Parameter ($\alpha$) of the Three Lands Uses

| Parameter | Land use | | | LSD |
|---|---|---|---|---|
| | Native grassland | Brome grassland | Cultivated | $\alpha$=0.05) |
| Bulk density ($Mg/m^3$) | 0.73a | 1.05b | 1.19c | 0.13 |
| Total porosity (%) | 72.64a | 60.31b | 55.04c | 5.20 |
| Macroporosity (%) | 30.26a | 12.80bc | 6.70c | 15.42 |
| Ks (cm/min) | 0.099a | 0.053a | 0.049a | 0.07 |
| $\alpha$ (1/cm) | 0.20a | 0.15b | 0.11c | 0.04 |

Note: means followed by the same letter in rows are not significantly different from each other at p=0.05.

The relationship between average infiltration rate and water tensions for each land use is presented in Figure 1. Steady infiltration rates among land uses were not significantly different at 3 cm $H_2O$ tension. At 15 and 22 cm tensions, native grassland had significantly lower infiltration rates than brome grassland and cultivated land while brome grassland had intermediate infiltration rates. This implies that cultivated soils are able to absorb more water at lower matric potentials (i.e. higher water supply tensions) than native grassland and brome grassland.

The infiltration rate under grassland decreased more dramatically with the increase in tension. The highest slope was observed in native grassland. Therefore, the removal of larger pores from the infiltration process had the greatest effect on infiltration under native grassland.

Since the three sites are located very closely there will not be a difference in soil texture. The large differences in infiltrability between grasslands and cultivated soils suggest that grassland soils have a well-developed macropore structure. Owing to low macroporosity prevention of water flow from larger pores had a least effect on infiltration in cultivated land.

Generally, brome grass is taller than native grass. Therefore, brome grassland is more capable of trapping snow and keeping it on upland than native grassland. Hence wind transport of snow into the wetlands would be higher in native grassland. Canola stubble in the cultivated field also can trap snow to a certain extent. Due to comparatively higher Ks in brome grassland most of the snowmelt water may enter into the soil resulting little or no runoff under saturated condition. Snowmelt runoff would be higher in cultivated lands. In contrast, cultivated soils are able to absorb more rainfall or snowmelt under near saturated conditions.

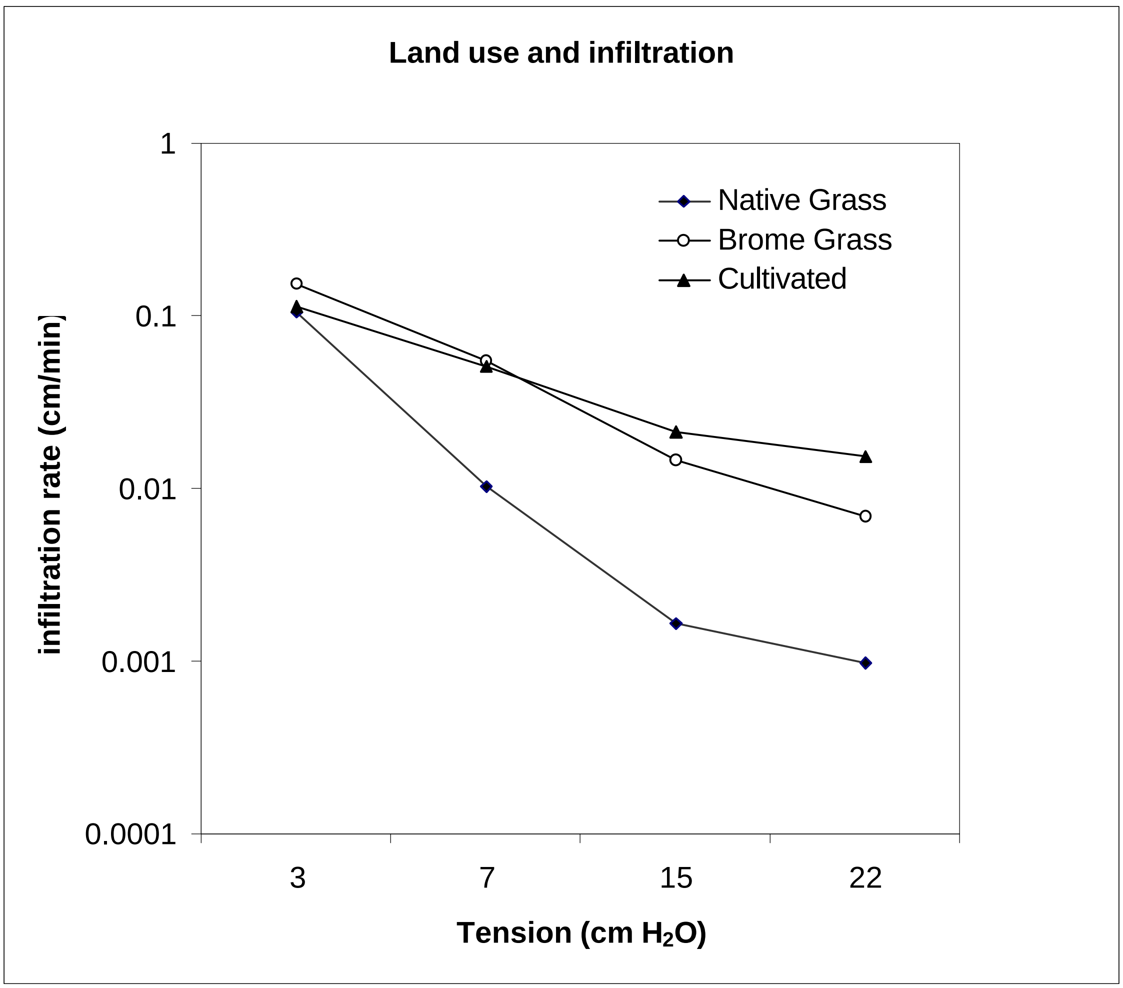


**Figure 1**. Effect of land use on steady infiltration rates at different tensions

The highest Ks was found for the brome grassland while the lowest Ks was observed for native grassland (Table 1). However, the differences were not significant at $p=0.05$. In addition, the estimated Ks values were lower than the steady infiltration rates at 3 cm $H_2O$ tension. It indicates that the data do not fit well into Wooding's equation that we employed for Ks estimation. Therefore, it is suggested to use inverse procedure for parameter estimation as suggested by Jaramillo et al. (2000).

The estimated $\alpha$ values were significantly different (p=0.05) among land uses (Table 1). The native grassland had the highest $\alpha$ value followed by brome grassland and cultivated soil, in descending order.

**Conclusions**

Results of the experiment revealed that the surface soil hydraulic properties vary considerably among land uses. Saturated hydraulic conductivity was higher in grasslands than cultivated fields. Macroporosity was highest in native grassland followed by brome grassland and cultivated lands in descending order. Hydraulic conductivity at 15and 22 cm water tensions, cultivated land had the highest conductivity followed by brome grassland and native grassland. Therefore, cultivated lands are able to absorb more rainfall and snowmelt than grasslands under unsaturated conditions. Land use changes may alter the water balance of the area by changing the amount of surface runoff and therefore, any changes in existing land use must be done cautiously.

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